Venus Interior Probe Using In-situ Power and Propulsion (VIP-INSPR)

Completed Technology Project (2017 - 2019)

Project Introduction

Venus, despite being our closest neighboring planet, is under-explored due to its hostile environment. The atmosphere is composed primarily of CO2, with a 92 bar pressure and 467°C temperature at the surface. The temperature decreases at higher altitudes, approaching conditions similar to that of Earth's surface at 65km. Due to more moderate conditions above 50 km, balloon missions have survived as long as 46 h at an altitude of 54 km. However, due to the opacity of the Venus atmosphere, orbital/balloon observations at such altitudes are not capable of characterizing the surface. The recent decadal survey for Planetary Science (2013-2022) and VExAG study (2014) emphasized the need to gather basic information on the crust, mantle, core, atmosphere/exosphere and bulk composition of Venus through in situ investigations, using low-altitude aerial platforms or land probes. The hostile conditions prevalent at low altitudes and on the surface of Venus have limited the low-altitude aerial or surface missions to a few hours (Russian Venera landers <2 h), due mainly to the lack of adequate thermal resilience of electronics and power sources. Since photovoltaic and nuclear power sources are currently inapplicable at low altitudes, there is a crucial need for new long-lasting power technology concepts to enable extended low-altitude aerial missions.##We propose to develop a novel Venus Interior Probe Using In-situ Power and Propulsion (VIP-INSPR) architecture for sustained Venus atmospheric exploration. The probe utilizes H2 and O2, harvested through electrolysis of sulfuric acid/water to supplement fuel carried from Earth, in order to supply a solid oxide fuel cell (SOFC) for power generation at low altitudes, and to supplement H2 as a buoyancy gas for the ascent/descent of a balloon. The major components include: i) A high temperature reversible SOFC, ii) Chemical hydride for H2 storage, iii) A H2 buoyancy-based altitude control system, and iv) A solar array, to generate power in the upper atmosphere. A solar array will power the probe at high altitude and the SOFC will provide power at low altitudes using H2 and O2 carried from Earth. Both H2 and O2 will be regenerated through electrolysis of the water produced in the fuel cell (a closed-system) at high altitudes. Additionally, these reactants will be replenished by electrolyzing either H2SO4 or H2O harvested from the Venus atmosphere at high altitudes to compensate for the loss of H2 from the balloon and/or water from the fuel cell. This novel architecture enables generation of fuel from in-situ resources at high altitudes, power at low altitudes, and transport gas for the balloon. In contrast to earlier Venus probes, our Venus probe is designed to survive the range of hostile environments on Venus without the need for thermal management. Cycling between high and low altitudes (e.g., 65k to 15km), the probe can be utilized as a long duration low-altitude aerial platform for Venus exploration. This would enable new scientific studies on the Venus inner atmosphere and surface geology using advanced analytical and imaging techniques.##The component technologies used here, i.e., metal hydrides, SOFC and a high-temperature solar array, have terrestrial relevance and will enable a new mission paradigm for Venus exploration. In Phase-1, we formulated the

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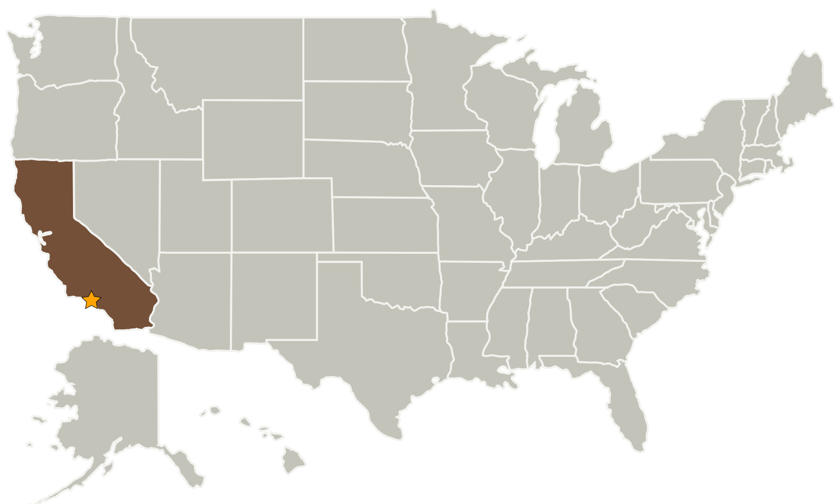
requirements of the component technologies and identified the materials based on thermal stability and performance. We have established an appropriate protocol for the lowaltitude and high-altitude transitions of the probe and developed a preliminary design for a 150kg balloon. In Phase-II, we will continue this development, focusing on key aspects relevant to a broader range of missions, identifying and advancing enabling technologies and developing a technology road map for incorporation in future Venus missions. We expect maturation of this concept at the end of the project to TRL 3.

Anticipated Benefits

The component technologies used here, i.e., metal hydrides, SOFC and a high-temperature solar array, have terrestrial relevance and will enable a new mission paradigm for Venus exploration.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Jet Propulsion Laboratory(JPL)	Lead Organization	NASA Center	Pasadena, California

Primary U.S. Work Locations
California

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Jet Propulsion Laboratory (JPL)

Responsible Program:

NASA Innovative Advanced Concepts

Project Management

Program Director:

Jason E Derleth

Program Manager:

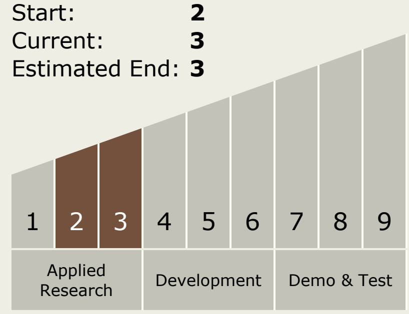
Eric A Eberly

Principal Investigator:

Ratnakumar V Bugga

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Project Transitions

April 2017: Project Start

March 2019: Closed out

Closeout Link: https://www.nasa.gov/feature/venus-interior-probe-using-in-situ-power-and-propulsion-vip-inspr

Links

NASA.gov Feature Article
(https://www.nasa.gov/feature/venus-interior-probe-using-in-situ-power-and-propulsion-vip-inspr)

Technology Areas

Primary:

- TX11 Software, Modeling, Simulation, and Information Processing
  - └ TX11.1 Software Development, Engineering, and Integrity
    - └ TX11.1.2 Verification and Validation of Software systems

Target Destination

Others Inside the Solar System